UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio Fall 1999

Air Force Materials Scientists Use Night Vision Goggles to Develop Vein Viewing System

An inquiry from medical personnel at the Walter Reed Army Institute of Research has led to a breakthrough in technologies used for viewing patient veins. This invention provides a clear view of veins under a variety of lighting conditions and has the potential for a variety of applications.

During discussions with Army medical personnel, Air Force Research Laboratory Materials and Manufacturing Directorate scientists learned that prompt insertion of an IV is often impossible under the low ambient light conditions of the battlefield. This invention overcomes the problem by providing a clear view of a wounded soldier's veins under a variety of difficult lighting conditions, from twilight to total darkness. This type of viewing is necessary to insert a catheter in order to save the lives of accident or trauma victims, to draw blood, or detect the infusion of new blood vessels that permits the rapid growth of cancerous tumors.

Conventional methods for finding a patient's veins rely on tactile and visual cues using available visible light only. The essence of the AFRL scientists' invention is night vision goggles (NVG) equipped with special filters to see infrared light that passes through the body but is partially blocked by the blood in the veins. During initial experiments, the AFRL scientists were able to clearly see the network of veins in fingers, hands, lower arms and feet using a TV remote control light source and a standard military NVG. Their studies showed this is due to the absorption of the infrared light by the deoxygenated hemoglobin traveling in veins. Bone, muscle and other tissue are not viewed since they transmit or scatter the infrared light instead of absorbing it. The inventors also verified that skin color does not affect the ability to view veins. Furthermore, experiments using various bandwidth light sources and optical filters under lighting conditions ranging from full room light to no light were performed to determine the optimum imaging characteristics of the invention. Other experiments verified that a needle inserted beneath the skin is clearly visible because metal blocks infrared light. Consequently, objects under the skin such as bullets or shrapnel can also be detected.

A prototype has been demonstrated at three Ohio medical institutions: Wright Patterson Medical Center, Cincinnati Childrens Hospital Medical Center and Columbus Childrens Hospital.

A neonatal intensive care physician at the Columbus Childrens Hospital examined an infant with the prototype device after receiving consent from the father, and was amazed he could see the network of veins along the baby's entire arm. Many physicians have commented that this technology would alleviate a great deal of suffering by patients, especially infants, who must undergo painful medical procedures requiring access to veins, such as drawing blood and IV insertion.

The breadth of this technological achievement encompasses countless civilian applications including emergency medical services (EMS), emergency room trauma centers, blood banks, pediatric and geriatric care facilities, and a variety of surgical procedures.

An application for a patent has been filed and is under consideration by the United States Patent and Trademark Office. It is anticipated that by the end of this year a patent will be issued. The Materials and Manufacturing Directorate is working to transition this technology with the award of an exclusive license to a commercial firm. This will permit clinical trials and expeditious approval from the Food and Drug Administration.

CALENDAR OF EVENTS

International Workshop on ZnO
October 7-8, 1999 - Dayton, OH

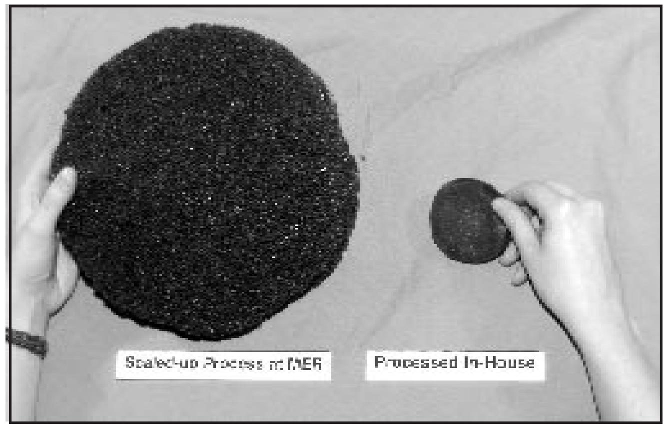
6th Workshop on 3-D Strength Prediction of Composite Joints
October 14, 1999 - Wright-Patterson AFB, OH

Symposium on "Materials for Optical Limiting III" at the 1999 Materials Research Society Meeting
Nov 30-Dec 3, 1999 - Boston, MA

Aging Aircraft 2000 . . . The 4th Joint DoD/FAA/NASA Conference on Aging Aircraft
May 15-18, 2000 - St. Louis, MO

Materials R&D Success Stories

Enlarged Graphitic Foam Sample Advances Applications Testing



Scientists at the Air Force Research Laboratory's Materials and Manufacturing Directorate (ML), working with the MER Corporation of Tucson, Ariz., have successfully manufactured a larger test sample of graphitic foam, a composite material that may substantially reduce the production time required to make aircraft structural components.

Graphitic foam is an ultra-stiff, ultra-lightweight composite that offers three-dimensional isotropic strength. The larger, sample, measuring one-foot in diameter by four inches thick, will enable researchers to create a more thorough database and provide material for applications testing. The use of graphitic foam could eventually save the Air Force millions of dollars, and lead to innovative commercial applications.

Since their development in the 1960s, composite materials have been widely adopted for high performance applications demanding ultra-stiff, ultra-lightweight structures. Prime examples of their use in Air Force systems include aircraft fuselage components and leading and trailing edges on aircraft wings. Composite materials for large components are usually made of continuous carbon fibers, which are laid up by hand. Composites are also made into honeycomb cores and covered with a cloth face sheet to produce lightweight panels.

Most composite materials for aircraft applications are made using a two dimensional lay-up technique that provides strength across the x and y-axes but little or no strength on the z-axis. While offering extraordinary mechanical properties, composite part production is labor intensive and time consuming. ML's Structural Materials Branch conducted an in-house study to find ways to exploit the extraordinary properties of aligned graphitic crystallites. Instead of melt-spinning the pitch into carbon fiber, they tried to produce structural foam. They discovered that the microcellular structure with 75-95 percent porosity developed a ligament-like configuration. They developed a process that can be tailored to produce uniform foams of various pore sizes and densities. The resultant open-celled foam is typically made up of microcellular bubbles averaging 10 to 150 microns in size (depending on foam density) with short, strong ligaments of graphitic crystallites aligned in every direction for favorable high strength properties. Direct net shape molding of graphitic foam can eliminate time-consuming hand lay-up steps required with continuous fibers and provide twice the projected stiffness of aluminum core.

As a replacement for graphite honeycomb core material, graphitic foam can be molded to the required net shape directly into the face sheet fabric for integral bonding and efficient co-curing, without requiring separate adhesive bonding and molding steps. In terms of density, graphitic foams with 90 percent porosity are projected to have nearly three times the stiffness of aluminum honeycomb; however, unlike honeycomb, the foam has isotropic mechanical properties. Another potential application uses graphitic foam as supercapacitor structures for power storage in density-sensitive applications, since they offer considerable area per unit of weight.

The successful fabrication of an up-scaled test sample represents an important milestone in graphitic foam's evolution. The enlarged sample, developed in cooperation with the MER Corporation, will make it possible to more accurately measure graphitic foam's material properties, develop a thorough database, and more thoroughly test the material for military and commercial applications.

Graphitic foam offers much potential as an ultra-stiff, ultra-lightweight structural material for Air Force aircraft and spacecraft applications. Rather than the two dimensional strength of traditional fiber-based composites, graphitic foam with microcellular structure provides strength through all axes. Direct, single-step net shape molding of graphitic foam can simplify part production and replace hand lay up or honeycomb adhesive bonding operations.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 99-262.

Visit us at www.afrl.af.mil

Sprayforming Technology Streamlines Aircraft Gas Turbine Engine Manufacturing

A research effort managed by the Air Force Research Laboratory Materials and Manufacturing Directorate and sponsored by the Defense Advanced Research Projects Agency (DARPA) has led to the successful development of a revolutionary process that streamlines aircraft gas turbine engine manufacturing.

The new process, called sprayforming, eliminates most of the steps used to make aerospace rings and casings for gas turbine engines and lowers the materials costs of components by as much as 30 percent. The new process also enables rapid response prototyping, small lot production and reduces the lead-times for component deliveries.

The successful transfer of sprayforming technology to the aerospace industry, already in progress, will speed up engine production. It will also provide a major edge in a global components market exceeding $270 million and could save U.S.-based engine manufacturers more than $40 million a year.

Developed under a $13 million DARPA research program, sprayforming uses a direct one-step conversion approach for superalloy ingots, near net shape capability and rapid metal deposition rates to provide a highly effective alternative fabrication process.

(see Sprayforming p3)

International Team Discovers New Materials Design Method Using Neurocomputing

Scientists at the Air Force Research Laboratory Materials and Manufacturing Directorate, interested in seeking a computational approach to predicting the existence of a multi-element compound, sponsored a collaborative research effort which led to a significant breakthrough in using neural networks to help design new materials.

The team discovered that a nonlinear expression involving an elementary material property could be used to predict, with greater than 99 percent accuracy, the existence of a compound for a multi-element materials system. This discovery will result in significant savings in time and resources and will speed the search for future, yet-to-be-realized, potentially useful materials.

There are about 5,000 binary (composed of two element), 162,000 ternary (three element), and roughly four million quaternary (four element) materials systems possible, according to Dr. Steven R. LeClair, materials scientists and chief of ML's Materials Process Design Branch. Of course, many of these combinations do not form compounds, and of those that do, data exists for only 80 percent of the binary systems, five percent of the ternary systems, and less than one percent of the quaternary systems.

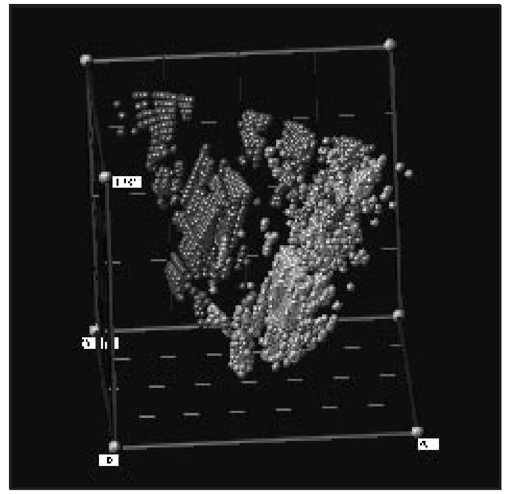
Dr. LeClair's Branch, together with the Air Force Office of Scientific Research (AFOSR), provided funding to Dr. Pierre Villars of Switzerland to establish an international research project which addressed strategies for accelerating materials design. Dr. Villars is a world-renowned expert in crystallography and a source for many of the world's materials data handbooks. The project took advantage of Dr. Villars' access to quality materials data and leveraged an existing AFOSR initiative referred to as Electronic Prototyping, involving basic research in recursive linear regression and adaptive stochastic optimization as applied to function approximation.

Electronic Prototyping is a research effort wherein the goal is for all devised artifacts to be prototyped electronically to simulate shape, processing and operation in an intended environment, Dr. LeClair explained. The objectives of this initiative are to develop new computational methods to model and relate materials-product-process designs; integrate, synthesize, and generalize new knowledge; and automate knowledge discovery for use in improving productivity.

By combining their expertise and leveraging resources, in April 1999, Dr. Villars and the Electronic Prototyping research team made a significant breakthrough. They discovered that a nonlinear expression involving an elemental property could be used to predict the occurrence of a compound for a multi-element (binary, ternary, etc.) materials system. The material property, referred to as the Mendeleev Number, was originally conceived by D.G. Pettifor (Oxford University, England) to group binary compounds by structure type.

"This discovery will save a tremendous amount of time and resources in the exploration of future, yet-to-be-realized, materials systems, particularly the four million quaternary systems on which there is little data," Dr. LeClair said. These quaternary systems include high temperature superconductors (e.g., YBaCuO), photonics/optical semiconductors (e.g., InGaAsP), and piezoelectrics (e.g., $PbZrTiO_3$), and a host of other compounds exhibiting unique combinations of properties which will enable new, more advanced technologies for tomorrow's aerospace force.

"We now have a computational approach to determining which combinations of elements will yield compounds that may lead to potentially useful materials," Dr. LeClair said. Longer term, this ability to computationally predict compound formation will motivate continued research of methods to predict specific combinations of properties, which ultimately will enable an end-user to select a material, or material alternatives, by simply specifying operational requirements.



A 3-D graphic involving three expressions of the Mendeleev Number which clearly depicts the hyperspace separation of over 4,000 ternary (three element) compounds.

In addition to Drs. Villars and LeClair, the team members included: Dr. Al Jackson, Technical Management Concepts Incorporated; Professor Yoh-Han Pao, Case Western University; Dr. Boris Igelnik, Case Western University; Professor Mark Oxley, Air Force Institute of Technology; Professor Mike Kirby, Colorado State University; Professor Bhavik Bakshi, Ohio State University; and Professor Phillip Chen, Wright State University.

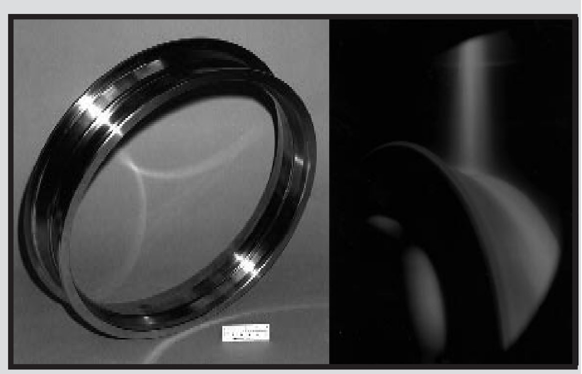
For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 99-233.

(Sprayforming)

Sprayformed superalloy components exhibit mechanical behavior characteristics comparable to current forged and wrought components, but at a significantly reduced production cost. Sprayformed materials have a more uniform homogeneous microstructure, resulting in improved machinability and inspectability and fewer billet related defects.

The primary contractors involved in the development of sprayforming for rings and casings, Pratt & Whitney and Howmet, have formed a joint venture, Sprayform Technologies International (STI). STI has a development unit with a melt capacity of a half ton with a maximum size capacity of 30 inches diameter. Soon a new production unit will have a melt capacity of 2.7 tons and the size capacity of 60 inches diameter necessary for commercial aerospace engines. Currently, High Pressure Turbine (HPT) and High Pressure Compressor (HPC) casings are being certified for insertion in the F100 and F119 families of gas turbine engines. In addition, Pratt & Whitney has identified more than 20 mature engine parts for sprayform processing using IN718, Waspoloy and Thermospan superalloys with a projected cost savings of $5 million per year.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 99-188.



NEW CONTRACTS

- Lightweight, Low Thermal Conductivity Thermal Protection System - F33615-99-C-5002
- Innovative Thermal Protection Materials - F33615-99-C-5010
- Highly Ordered Conductive Polymer Coatings - F33615-99-C-5011
- Robust Rod-Coil Films For MEMS Lubrications - F33615-99-C-5014
- Winchem: A Tool For Evaluation Of High Structural Material - F33615-99-C-5204
- Probabilstic Micromechanical Fatigue Model - F33615-99-C-5213
- Forging Supplier Initiative - Pratt & Whitney - F33615-99-2-5303
- Forging Supplier Initiative - General Electric - F33615-99-2-5304
- Replacement Of Conventional Chrome Plating Process - F33615-99-2-5309
- Epitaxial Growth Of Silicon Carbide (SiC) - F33615-99-C-5413
- Nano-Engineered Magnetic Materials For High Temperature - F33615-99-C-5420
- KTP For High Repetition Rate And Continuous Wave Application - F33615-99-C-5421
- Application Of Commercial Parts Obsolence Management (CPOM) - F33615-99-2-5500
- Physics Of Failure Approach To Sustainable Electronic Systems - F33615-99-2-5503
- Affordable Millimeter Wave Units - F33615-99-2-5504
- Flexible Space Vehicle Production Line - F33615-99-2-5505
- High Temperature, Long Service-Life Fuel Cell Bladder Materials - F33615-99-C-5600
- Shelf-Stable, Low-Temp Cure Epoxy Film Adhesive For On-Aircraft - F33615-99-C-5602
- Selective And Dry Nickel-Based Superalloy Etch Process - F33615-99-C-5603
- Novel Room Temperature Method For Rapid In Situ Removal - F33615-99-C-5604
- Near Real-Time Monitoring Of Thin-Film Materials - F33615-99-C-5701
- Laser Induced Flouresence Imager For Closer Loop Epitaxial - F33615-99-C-5707

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